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| **From:** | **Chris Emery – ENVIRON** |
| | **Nicole Downey, Ph.D. – Earth System Sciences, LLC** |
| **To:** | **CASAC Ozone Review Panel** |
| **Date:** | **June 3, 2014** |
| **Subject:** | **Clarifying statement regarding effects of NOx emission reductions on ambient ozone concentrations** |

During the May 28th CASAC teleconference there was apparent confusion about how ozone responds to different types of emission reductions (i.e., NOx-only or NOx+VOC) and how EPA modeling predicts alternate scenarios. The discussion centered on the idea that EPA's health effects estimates were biased because EPA used a NOx-only emission reduction scenario, which would amplify the reduction in low ozone hours due to decreased NOx scavenging. The discussion continued when a panelist stated that EPA should find an emission reduction scenario that reduces peak ozone without an associated increase in low ozone. Chris Emery raised this point in his clarifying comments submitted on May 29.

We offer a clarification regarding that discussion, by comparing simulated 2006 ozone responses to NOx-only, VOC-only and NOx+VOC emission reduction scenarios in four cities to meet a 65 ppb alternative standard (Figure 1), according to our HDDM modeling as previously reported (Yarwood et al. 2013, Downey et al., submitted). Table 1 lists NOx and VOC reductions necessary to reach 65 ppb, and the city-wide peak 4th highest maximum daily 8-hour ozone, for each scenario by city. The following features are evident from this comparison:

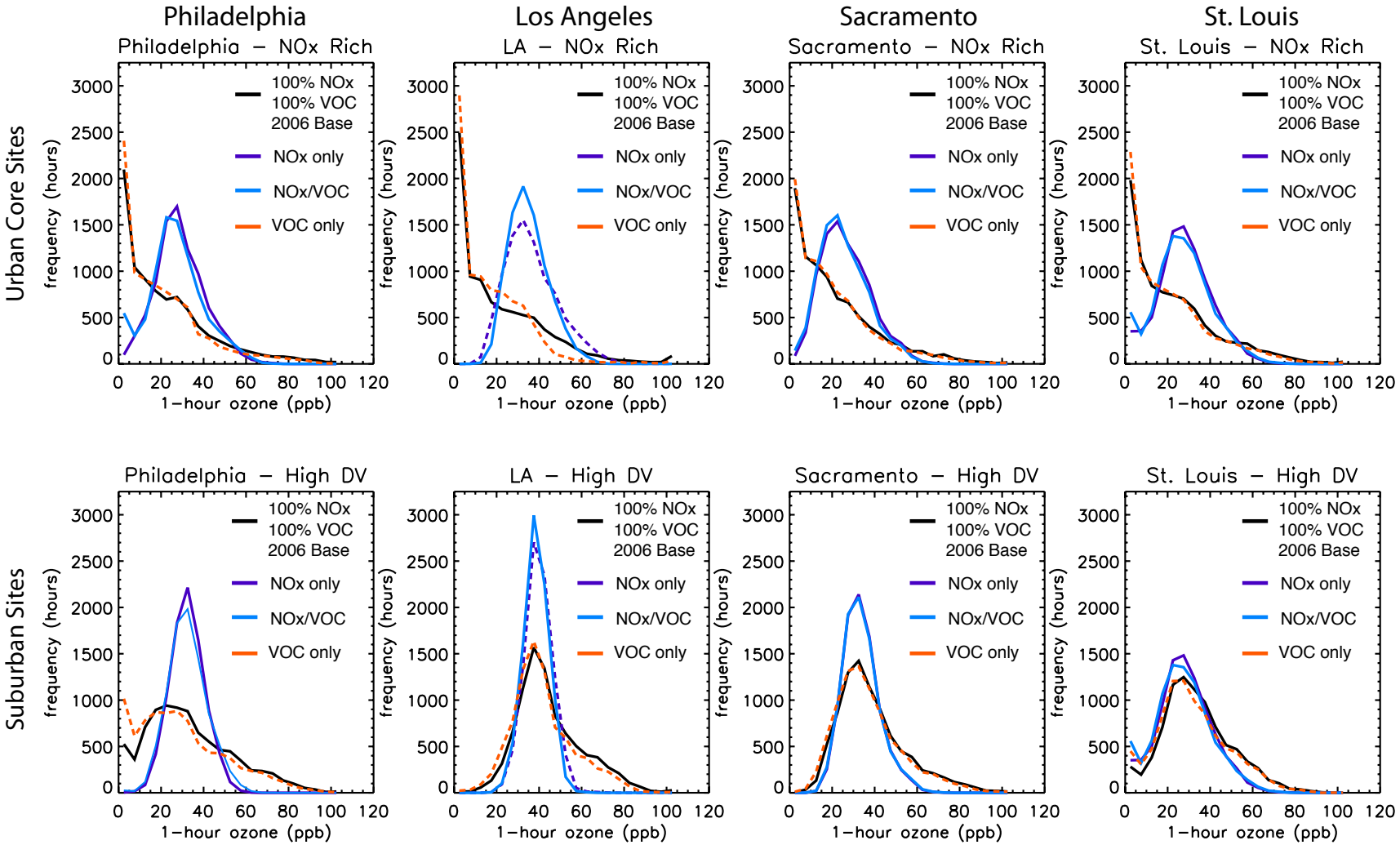
- There is very little difference in the frequency of low ozone hours between an emission reduction scenario that employed NOx-only and equal NOx+VOC emission reductions to attain a standard of 65 ppb.
- Reducing VOCs leads to minimal changes in base ozone, and no city is able to attain a standard of 75 ppb or less using VOC emission reductions alone.
- There is no scenario that reaches a standard less than 75 ppb that does not employ some level of NOx reductions.
- The high frequency of very low-level ozone concentrations currently observed in urban core areas is caused by anthropogenic emissions of NOx. Reducing anthropogenic emissions of NOx will decrease the frequency of very low-level ozone hours, decrease the frequency of high-level ozone hours and increase the frequency of mid-level ozone hours. There is no attainment strategy that will simply push down the entire ozone distribution or avoid an increase in the frequency of mid-level ozone at NOx rich sites due to the non-linear chemistry of ozone.

**References:**

Downey, N., Emery C., Jung, J., Sakulyanontvittaya, T., Hebert, L., Blewitt, D., Yarwood, G., 2014. Emission reductions and urban ozone responses under more stringent US standards. Submitted – Atmospheric Environment.

Yarwood G., Emery, C., Jung, J., Nopmongcol, U., Sakulyanontvittaya, T., 2013. A method to represent ozone response to large changes in precursor emissions using high-order sensitivity analysis in photochemical models. Geoscientific Model Development, 6, 1601–1608, doi:10.5194/gmd-6-1601-2013.

Figure 1




Hourly ozone frequency distributions at both NOx rich sites (urban core) and high peak ozone sites (suburban) in Philadelphia, Los Angeles, Sacramento and St. Louis. Black lines are 2006 modeled frequency distributions emulating observations. Purple lines show frequency distributions for NOx-only emission reductions reaching a 4th highest MDA8 of 65 ppb (except Los Angeles, where 65 ppb was not attainable with NOx-only emission reductions). Blue lines show hourly frequency distributions for equal NOx+VOC emission reductions reaching a 4th highest MDA8 of 65 ppb. Red lines show hourly frequency distributions when anthropogenic VOC emissions are eliminated, but NOx emissions are held at 2006 levels. These figures clearly demonstrate that NOx-only emission reductions lead to a similar increase in the frequency of mid-level ozone as NOx+VOC emission reductions, and that VOC emission reductions alone do little to reduce high ozone values below 75 ppb. Dotted lines represent cases where a standard of 65 ppb was not attainable.

# Table 1

| | NOx Only Emission Reductions | | | NOx and VOC Emission Reductions | | | VOC Only Emission Reductions | | |
|---|---|---|---|---|---|---|---|---|---|
| | 4th highest MDA8 (ppb) | % NOx remaining | % VOC remaining | 4th highest MDA8 | % NOx remaining | % VOC remaining | 4th highest MDA8 | % NOx remaining | % VOC remaining |
| Los Angeles | 84 | 10 | 100 | 64 | 5 | 5 | 106 | 100 | 0 |
| Philadelphia | 63 | 18 | 100 | 65 | 22 | 22 | 95 | 100 | 0 |
| Sacramento | 65 | 19 | 100 | 65 | 19 | 19 | 103 | 100 | 0 |
| St. Louis | 65 | 21 | 100 | 65 | 24 | 24 | 90 | 100 | 0 |

Percentages of anthropogenic NOx and VOC emissions remaining after meeting a standard of 65 ppb for cases where 1) VOC emissions were held constant and only NOx emissions were reduced, 2) VOC + NOx emissions were reduced by equal amounts and 3) VOC emissions were reduced and NOx emissions were held constant. Cells highlighted in yellow did not meet a standard of 65 ppb with the reductions shown here. For the NOx-only emission reduction case in Los Angeles, we did not reduce NOx emissions below 10% due to numerical instability in HDDM sensitivities (similarly reported by EPA in the HREA).